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N-804

REPORT OF THE ADVISORY COMMITTEE
ON FLOATING PLATFORMS

A. J. Tachmindji

November 1971

INSTITUTE FOR DEFENSE ANALYSES
// SYSTEMS EVALUATION DIVISION
400 Army-Navy Drive
Arlington, Virginia 22202

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Report of the Advisory Committee
on Floating Platforms

INTRODUCTION

The Advisory Committee was convened at the Institute for Defense Analyses on November 3, 1971. The membership of the Advisory Committee is shown in Appendix A.

The Panel was briefed on:

- a. The objectives of the ARPA program.
- b. The background of the Scripps Institution of Oceanography program.
- c. The dynamic effects of the platform including computer simulations and model results.
- d. The design and technical aspects of the platform.
- e. The structural aspects of the platform.

The agenda of the meeting is shown in Appendix B.

Objectives and Purpose of the Advisory Committee

The following is a list of the objectives and purpose of the Advisory Committee.

1. The safety and seaworthiness of the concept.
2. The ability of the concept to be extended in size, either by scaling the size of individual modules or by the addition of additional modules.
3. Technical issues which may arise from the design of the platform.

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4. Possible comments on costs and particularly as it affects the scalability of the concept for larger sizes.

The Committee was to examine the above aspects in view of its experience and knowledge in comparison with alternative approaches to these problems.

The Committee was not asked nor did it address itself to the possible applications of such platforms.

Platform Specifications

The concept has evolved and the specifications have been finalized to where Scripps now feels ready to proceed with the detailed design. The following are the basic present specifications for the stable platform:

1. Motion Response. Heave response of a single model is estimated about as good as FLIP requiring a vertical length of the legs of approximately 260 feet. The attenuation coefficient is estimated to be approximately 0.13, thus resulting in a 3.6-foot heave response for a 20-foot wave.
2. Displacement. Each platform (two-legged module) will have displacement approximately 6500 tons with about half of this displacement in the concrete structure.
3. Payload. Module payload will have a total payload of 196 long tons. The payload will not include service generators, machinery and other facilities.
4. Endurance. The system is designed for an endurance of approximately 30 days.
5. Stability. Each two-legged module must be stable and have a normal static G-B separation of approximately five feet.
6. Freeboard. Each module is designed to handle a 40-foot wave (80-foot crest to trough). Normal operating draft will be 20 feet. Means are provided for shifting solid ballast from mid ship tanks to bottom tanks in each leg and deballasting water ballast to permit an increase of air gap to 40 feet in the event of impending bad weather. Time for shifting ballast is estimated to be approximately 15 minutes.

7. Towing Speed. Each module has a catamaran configuration with the twin hulls towed at 6 to 7 knots.
8. Dimensions. Each module has a deck area of 80 by 51 feet.
9. Accommodations. Both modules will carry approximately a 24 man crew.

FINDINGS

General Comments

1. The Committee was generally impressed with the model work, computer calculations and techniques which have been used in determining motions, stresses, and design characteristics. It was felt that the design utilized the latest available information and procedures.
2. It appears to the Advisory Committee that design trade-offs have been conducted only for two modules. Little or no thought has yet been given the problems associated with extending the two model concept in both the X and Y directions in order to accomplish the ARPA objectives. Although it is realized that initially the program is to be constrained to two modules, it is felt that before the design is finalized, an examination must be made of the motions for fully coupled systems. The coefficients and forces as a function of the number of modules must be generated before finalizing the type of linkage needed and the design characteristics of each module. (See also comments in Appendix C.)
3. It is apparent to the Committee that the design is still under the process of evolution and that certain important technical aspects have yet to be addressed in sufficient depth. Of these, probably the most important is the finalization of the linkage mechanism and method of linking the modules.
4. The Committee questions whether the 40-foot clearance is sufficient to allow operations North of 40N during the winter in the Atlantic and in various areas of the Pacific. It would recommend that an examination of adding approximately 10 feet to each leg may be warranted at this time in order to ascertain the stability and dynamic effects of a 50-foot air gap. Such addition may be achievable with some additional cost.
5. In the event that the 40-foot design clearance is finalized, the Committee feels that the areas of operation, time of the year,

and operational windows must be determined in order to constrain operations to certain oceans.

6. Independently of the design air gap clearance (whether 40 or 50 feet), it is recommended that an examination of motions and stresses in extreme waves must be undertaken. Actual sea spectrum should be used rather than swell spectrum with the available statistics of rare events.

7. The Committee was concerned with the relatively low payload fraction of the platform (approximately 400 tons for a 13,000-ton displacement). Although it appears that design trade-offs were originally undertaken, the Committee feels that it would be useful, at this time, to undertake a payload-cost trade-off. It should examine whether it would be possible to increase the present design payload fraction (approximately 3 percent) in order for the platform to be competitive with existing drilling platform technology.

8. The Committee feels that the available technology of drilling floating platforms (as given in Table I, Appendix C and in Appendix D) may also be applicable to the ARPA problem. It should be noted that the typical drilling platform relies on its motion stability by increasing the virtual mass of entrained water for each leg; a capability which is not possible in the FLIP-type leg.

Table I
Comparison of ARPA and Commercial Platforms

	<u>FLIP Type Platform</u>	<u>Typical Drilling Platform</u>
		<u>Appendix D</u>
Displacement	Two Units 13,000 tons at 6500 tons/unit	11,150 tons (12,500 short tons)
Draft	260 ft	60 to 70 ft
Air Gap Clearance	20 or 40 ft	30 to 50 ft
Towing Speeds	140-170 Miles/Day	110 Miles per Day
Payload	app. 400 tons	~2000 tons ~3000 tons including machinery
Potential Deck Area	8000 ft ²	~20,000 ft ²
Accommodation	24 personnel	70 to 80 personnel
Stability	Good	Good
Motion	Good	Good
Station Keeping	To be provided	Good
Self Propulsion	Possible	Possible
Safety Record	Unknown	Known
Prototype Experience	No	Yes

9. The Committee was impressed with Scripps' understanding of the problems in mating together multi-module units in a sea state. It is felt, however, that unless the mating operation is to be carried out in a very calm area or is to be delayed until the sea has calmed to a workable condition, an attempt to mate two units with a relatively surge motion of seven feet and a relative heave motion of about three feet in any sea condition is a dangerous operation and may result in loss or damage to other life or property. (See also Appendix D.)

Specific Comments

1. It is felt that there are certain critical structural connections in the design of the legs. It would, therefore, be advantageous for the program to identify the critical structural stresses and decide on the structural criteria which constrains the design. After such an examination, it may be advantageous to conduct structural strength model tests in the critical structures (such as tee joints) which are extremely difficult to compute.

2. An attempt should be made to include slamming loads with the legs in both the horizontal and vertical positions in the stress design of the structure.

3. The Committee felt that the design team was very well aware of the critical design issues within each leg and, specifically, the intersection of the concrete bulkheads and the wall structure. Although the Committee realized that replacing concrete bulkheads with steel may require operational maintenance, it was felt that the stresses in these areas may be very critical, that substitution of steel for concrete should be considered. The Committee did not feel that improving concrete technology procedures should be an objective in this program and, therefore, compromises away from concrete should be considered.

4. Both the Committee and the design team are aware of the possibility of delamination of concrete structures. This is an area in which extremely careful manufacturing procedures must be followed.

5. The Committee felt that, in general, the concrete design was within the available technology and can be achieved but that the construction of such structures is tricky. Manufacturing processes with tight quality control will be required.

6. The Committee feels that means should be provided for testing the emergency ballast transference procedures.

7. The Committee recommends that the design team examine the possibility of connecting the four legs (in the vertical) through some strut or tie arrangement. This should improve both the stability and structural aspects. (See Appendix E.)

8. The Committee is somewhat concerned with the connection between the two modules which will allow the decks to move relative to each other and produce an uneven deck surface. This could be alleviated by the connection of the legs in the vertical.

9. The Committee felt that a design allowance must be made for possible absorption of water by the concrete structure if the exact concrete specifications are not exactly met.

Appendix A

Floating Platforms Committee

Professor J. Harvey Evans
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Appendix B

ARPA FLOATING PLATFORMS ADVISORY PANEL

November 3, 1971

AGENDA

- I. Convene
- II. Welcome
S. Lukasik
- III. Background
SIO Program - F. Spiess
- IV. Design and Technical Aspects - L. Glosten
& Associates
- V. Structural Aspects
- VI. Lunch
- VII. Executive Session
- VIII. Reconvene

Appendix C

Submission by
Mr. George Morgan



SUN OIL COMPANY POST OFFICE BOX 2880, DALLAS, TEXAS 75221



November 12, 1971

Mr. A. J. Tachmindji, Director
Institute for Defense Analyses
400 Army-Navy Drive
Arlington, Virginia 22202

Dear Mr. Tachmindji:

In accordance with your verbal request at the termination of the November 3rd meeting of the ARPA Advisory Committee on Floating Platforms, I am submitting herewith a copy of my assessment of the floating platform program to date (Enclosure 1).

In addition, I am forwarding a brief note, along with representative photographs, relating to an early investigation of stable platforms for midocean usage (Enclosure 2). If this early design test data is of interest to you, I will be glad to mail a more comprehensive description of the test with a discussion of the test results. Motion pictures of the tests are also available from the writer.

Also, I am enclosing sketches from a recent study which may contribute to a solution for bi-directional growth of your present hardware concept. Additional data are available from the writer on this concept of modularization (Enclosure 3).

May I take this opportunity to express my appreciation for the privilege of serving on your November 3rd advisory committee meeting for floating platform development.

Yours very truly,

George W. Morgan
George W. Morgan

ac

Enclosure 1
Enclosure 2
Enclosure 3

REPORT FROM MEMBER OF
APRA FLOATING PLATFORM ADVISORY PANEL

Reference: Meeting on November 3rd,
Institute for Defense Analyses
Arlington, Virginia

Report submitted by: George W. Morgan

Date:

Item 1. Modular Expansion Capability of the Floating Platform in Bi-lateral Modes

According to opening comments by Dr. S. Lukasik, the primary development objective of this program is the achievement of practical, mid-ocean floating platforms. The platforms would be candidates for use in future strategic and/or logistic support activities. As such, the concept must provide for both longitudinal and transverse dimensional growth capabilities for any given installation requirement.

The dimensional growth of the floating platform would be accomplished by sequential additions of compatible, modular, floating units. A basic modular concept, therefore is prerequisite to the development of practical hardware designs which permit the assembly of platform sizes and proportions as required. If, as a design by-product, the concept provided modular units for other purposes (such as ocean research facilities) this would be considered as the achievement of a secondary goal. The primary objective relates to military usage and must not be compromised in the development or achievement of secondary goals.

Dr. Wang added that important criteria included: (a) low fabrication cost, and (b) platform mobility as required for location changes.

Dr. F. Spiess (S10) followed with a discussion of the program background as seen by Scripps Institution of Oceanography. Primary emphasis was given by Dr. Spiess to design objectives relating to facilities for underwater acoustic research, sea floor research, and internal wave studies. Dr. Spiess traced the historical development of the current configuration, stating that one of their primary concerns related to the development of unilateral linkage techniques. The problem of expansion of platform area in an orthogonal direction was being postponed by S10 until the unilateral solution was properly achieved, Dr. Spiess stated.

Mr. L. Glostén, of L. Glostén and Associates, Naval Architects, next discussed various problem areas. One of the major areas of concern related to difficulties inherent in the linking of platforms in a unidirectional mode. No discussions were presented which related to bi-lateral linking.

From the standpoint of a reviewing advisory panel member, it appears that the concept being pursued by S10 is directed to a limited accomplishment of the program objective as stated by ARPA (S10 is emphasizing unidirectional modular growth in lieu of bi-directional modular growth). Even at best, however, the concept appears to have inherent problems in the achievement of its unidirectional growth capability. The approach to bi-lateral growth, in its broadest aspects, does not seem to have been sufficiently explored to warrant a presentation; in fact, various features of the present configuration appear to make bi-lateral growth extremely difficult. On the basis of these observations, it would appear that ARPA may wish to require that conceptual plans be developed by S10 for practical bi-lateral growth of the platform prior to the expenditure of additional funds for studies of the unilateral growth method. This approach might minimize the possibility of development testing on hardware solutions leading principally to ocean research, rather than for ARPA's more extensive program requirements.

Item 2. Considerations Relating to Prestressed Concrete Design

Fatigue properties of the prestressing steel should be considered. Heat-treated cold-worked alloy bars, along with their corresponding anchorage devices, should withstand a minimum of 3,000,000 loading cycles over a stress range of 85,000 to 10,000 psi without evidence of distress. A great deal of investigation should be denoted to maximum triaxial stress conditions (including shear). A minimum of creep and a maximum of resistance to fatigue loadings are of utmost importance in structures subjected to the oceanic environment.

In general, highly stressed steel is vulnerable to the action of sea water. Stress-corrosion is the deadly enemy of prestressing tendons. S-N curves for all metals which are highly stressed in sea water show an alarming degradation in strength properties. It is especially important to avoid the presence of nitrates. There is also some reason to believe that under such conditions it is wise not to permit more than one kind of cement to be in contact with any given prestressing tendon. Oil-tempered wire is much more sensitive to stress corrosion than other types. For these reasons, great effort should be made to protect all highly stressed steel from sea water exposure.

In the case of post-tensioned ungrouted tendons, it is good to use galvanized wire along with plastic or bituminous coatings. Joints between adjacent segments of the structure require special techniques to protect the longitudinal prestressing steel from the ocean environment.

Item 3. Considerations Relating to Bulkhead Joints

Structural joints between cylindrical sections and various types of bulkhead configurations have been widely studies in the last few years. Extensive test programs and comprehensive analytical studies have been devoted to the development of reliable joint geometries in metal and non-metallic tanks. Some of the theoretical work is applicable to the design of concrete tanks with internal bulkheads; however, a number of additional parameters exist in concrete design procedures which complicate and obscure some of the available experimental data.

The requirements of these extensive study and test programs relate to strain incompatibilities which inherently exist between bulkhead and cylinder structures when pressure loads are involved. This problem exists in both metal and concrete construction and secondary stress problems generally increase as the effective rigidity of the shells increase, meaning that concrete construction requires very special attention. Secondary stresses which result from strain incompatibilities must be attenuated without the development of destructive stress levels. A very common "trouble maker" (slope discontinuity) is associated with abrupt changes in slopes along meridional profiles (see α in Figure 1). For any given ratio of cylinder wall thickness to bulkhead thickness, the magnitude of the problem increases with abruptness of slope increase (α). In general, therefore, it is desirable to minimize the angle α at the joint.

Figure 2 illustrates the effect of minimizing the abruptness of change in load direction for a two-part joint (bulkhead and cylinder). Figure 3 shows the results of a computer print-out of the stress distribution at the intersection of a three-part joint (cylinder-bulkhead-cylinder). The notations used in Figure 3 are:

$$\sigma_u = \sqrt{\sigma_\phi^2 - \sigma_\phi \sigma_\theta + \sigma_\theta^2} \quad (\text{Von Mises failure criterion})$$

()_i = Inside face

()_o = Outside face

() _{θ} = Circumferential direction

() _{ϕ} = Longitudinal or meridional direction

()_x = Longitudinal direction

Changes in any one of the three rigidity parameters (flexural, extensional, shear) will greatly affect the stress distribution in the joint. The writer has the computer program used in this analysis and it is applicable to analyses of structures proposed for the ARPA Floating Platform.

Figure 4 is a graph which shows the ratio of maximum stress to hoop stresses resulting from pressure loadings of tanks with various types of bulkheads. Note that a flat-plate bulkhead with $\alpha=90^\circ$ can develop a maximum stress ratio of 14.

Figure 5 is similar to Figure 4, except that it pertains only to flat plates. Bulkhead and cylinder intersection joints can be analyzed both by numerical techniques and finite element modeling. If finite element models are utilized it is essential that flexural, extensional, and shear rigidities of the three intersecting shells be simulated. Many finite element models represent only one or two of these three rigidity properties, sometimes resulting in considerable error.

BULKHEAD TYPES

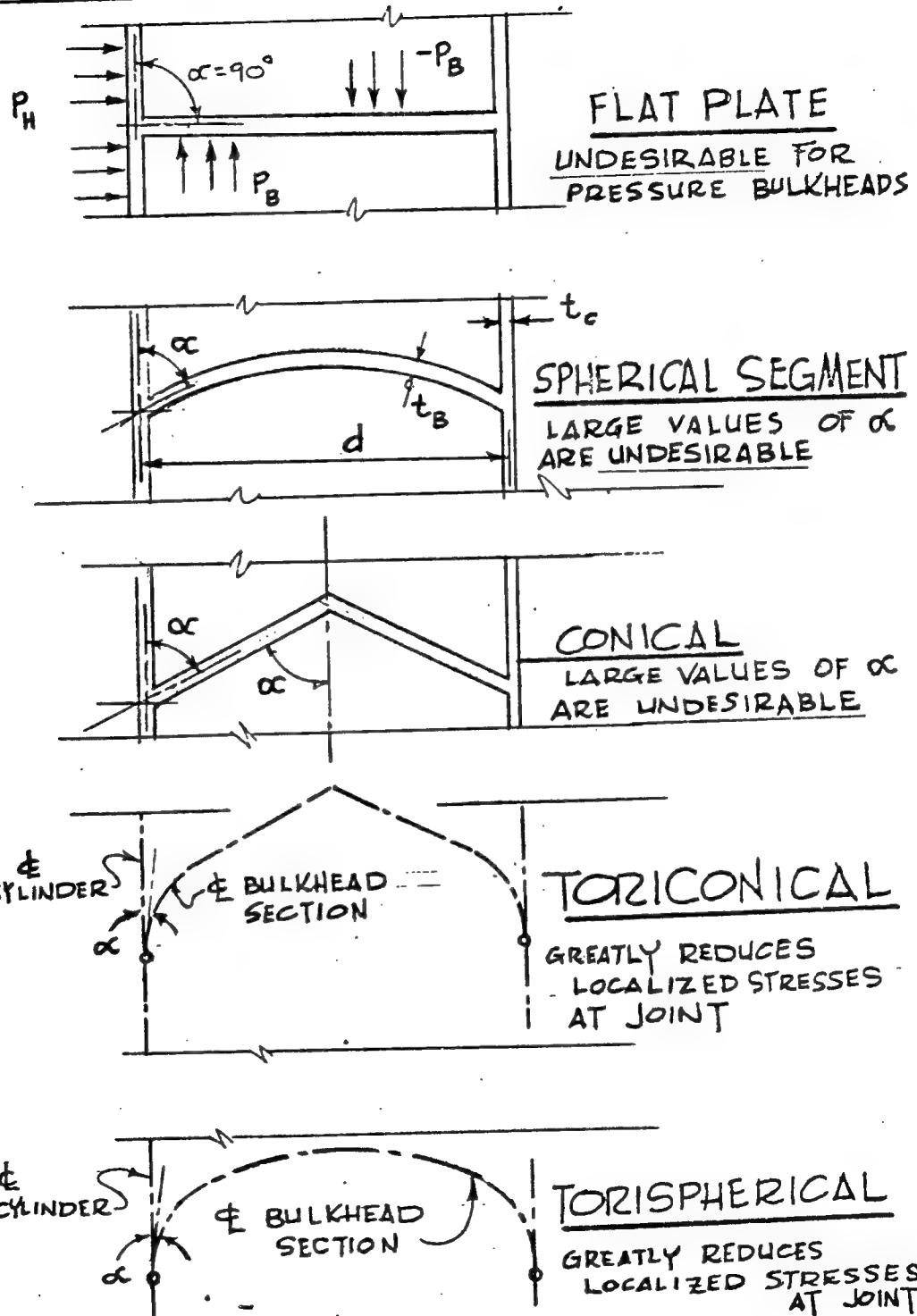


Figure 1. BULKHEAD TYPES (GEOMETRICAL CLASSIFICATION)

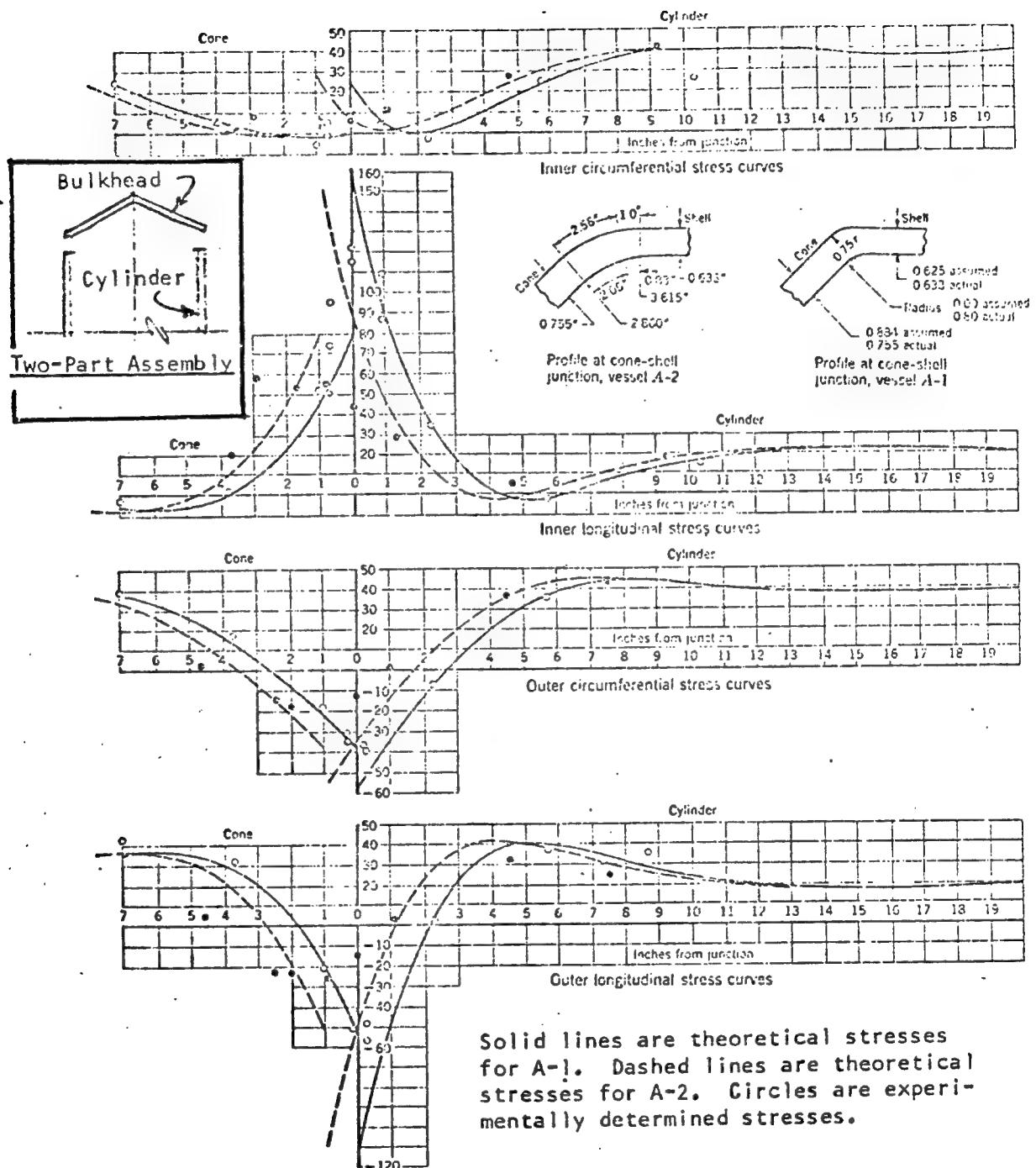


Figure 2. JOINT DISCONTINUITY STRESSES IN A TWO-PART ASSEMBLY

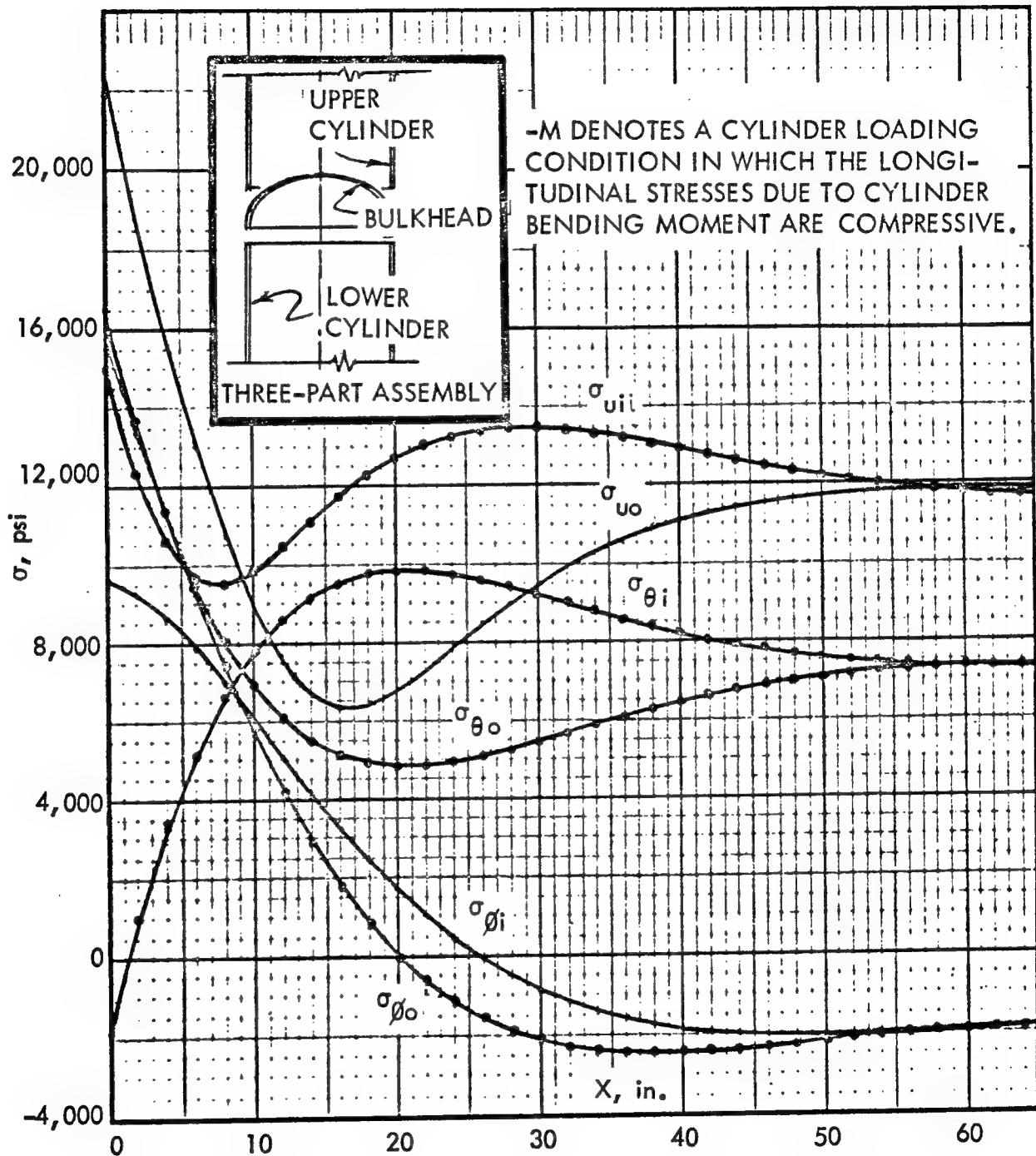


Figure 3. JOINT DISCONTINUITY STRESSES IN A THREE-PART ASSEMBLY SUBJECTED TO -M BODY BENDING MOMENTS

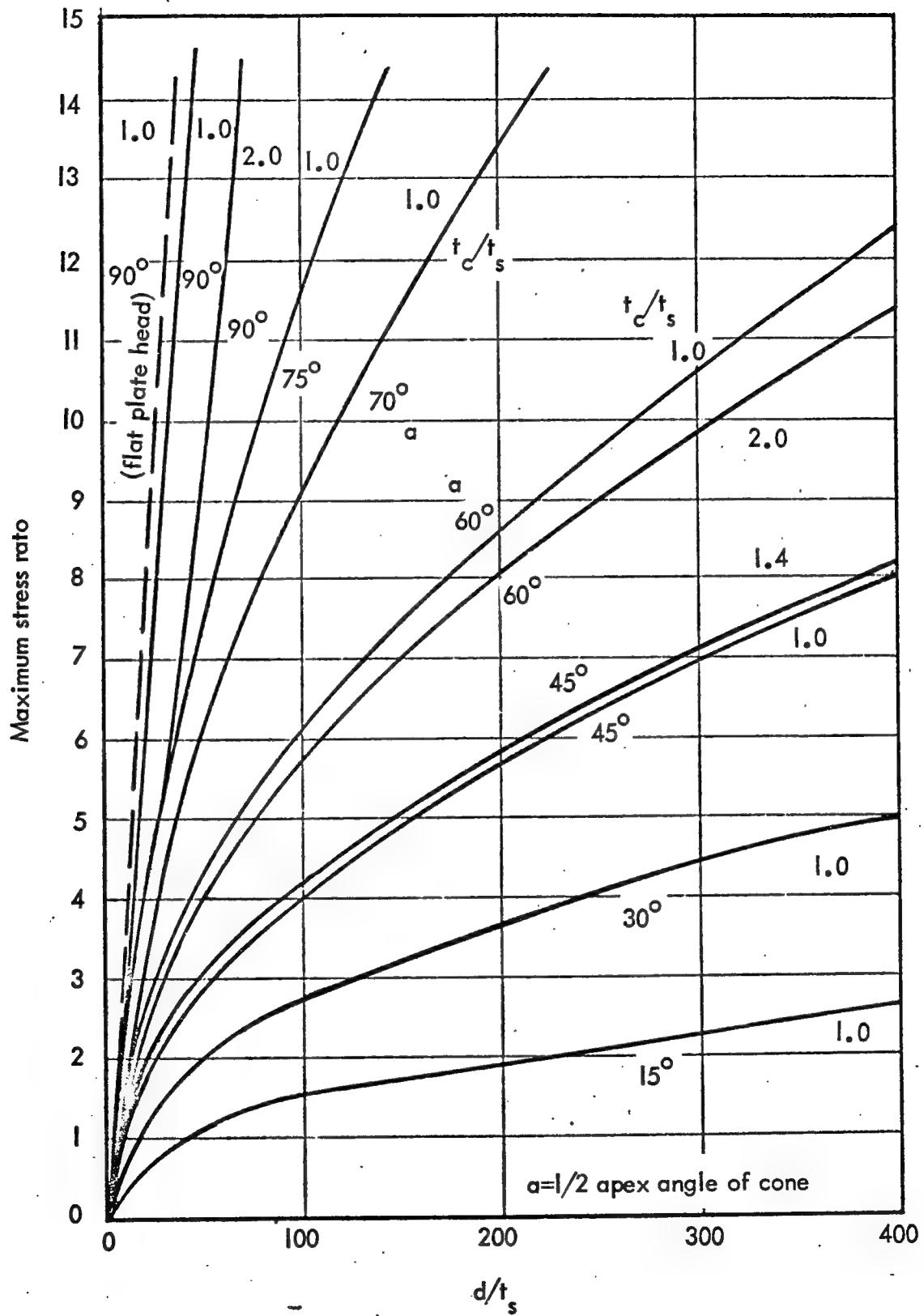
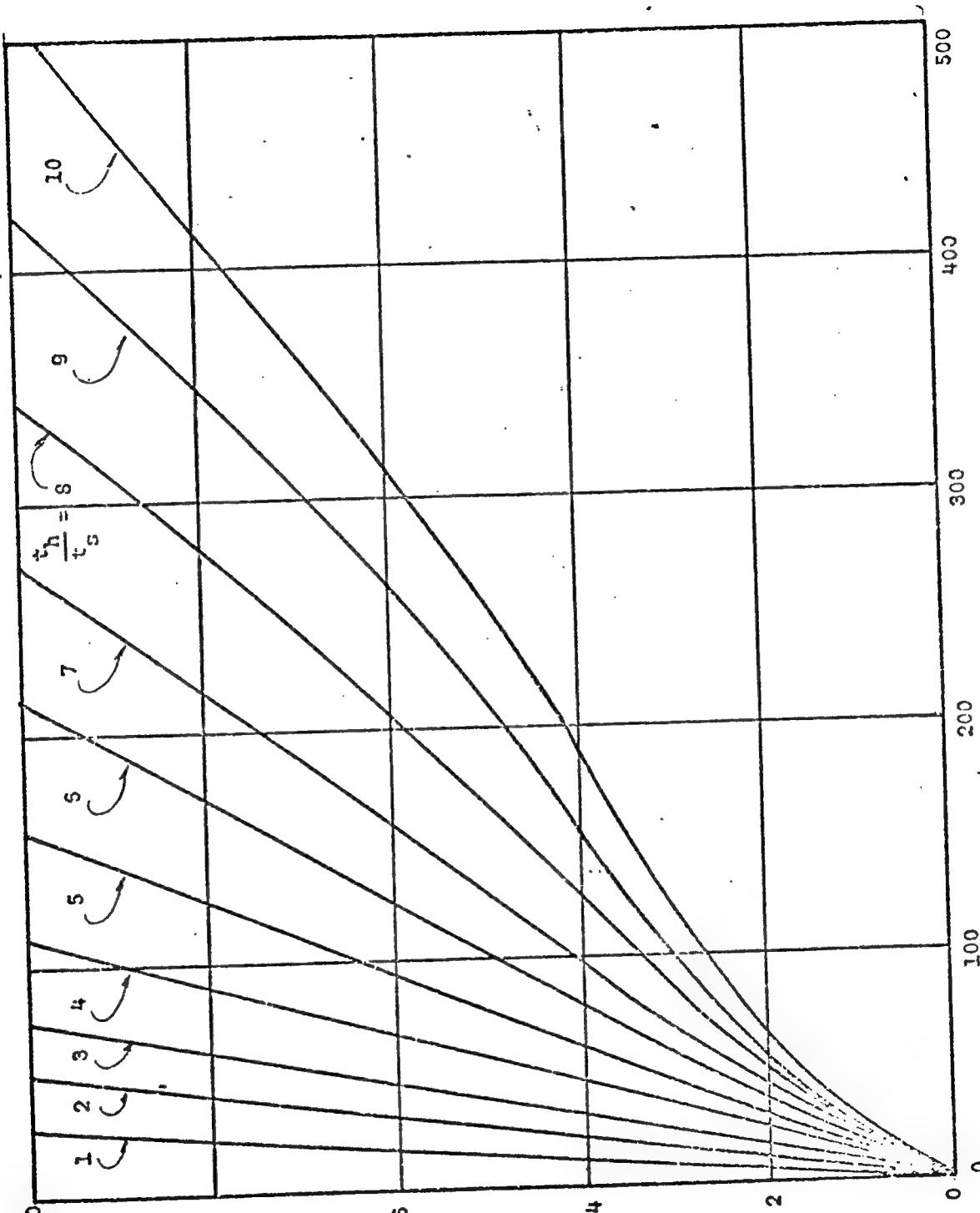


Figure 4. MAXIMUM STRESS RATIO IN THE SHELL AT JOINT OF TWO-PART ASSEMBLIES



$$f_{\max} = \frac{f_{\max}}{f_{\text{hoop}}}$$

Figure 5. MAXIMUM STRESS RATIO IN THE SHELL AT THE JOINT
IN FLAT-PLATE CLOSURES

November 12, 1971

Enclosure 2

SEADROME MODEL TESTS

During the years 1945 and 1946, a firm known as "Seadrome Patents Inc." of Philadelphia, Pennsylvania, under the direction of E. R. Armstrong, President, conducted tests to determine the engineering feasibility of a patented concept for floating air fields in the mid-ocean. The tests were conducted with a 1/25 scale model, representing an 1800-foot long prototype structure (see Figures 1, 2 and 3).

The tests were performed by Sun Shipbuilding and Dry Dock Company, Chester, Pennsylvania, under War Department Contract No. W44-009-eng-340. The War Department specified a prototype wave height of 35 feet and a wave length of 520 feet. These data were determined from studies of sea states at a tentative location selected by the Air Transport Command.

The 1/25 scale model tests were performed in a basin 200 ft. long, 24 ft. wide and 20 to 26 feet deep, alongside pier 13, No. 4 Yard. The test basin was enclosed by yellow pine sheathing driven into the mud and was left open at the river end. The wave maker consisted of a steel welded tank, shaped as a right triangular prism, which ran on vertical guides at the inshore end of the basin.

The 1/25 scale model tests were performed after several years of preliminary testing with 1/96 scale models by the Beach Erosion Board of the U. S. Engineers Corps.

The 1/25 scale test program confirmed previous claims that, with suitable arrangement and dimensional relationships of the buoyancy elements, wave motion such as might be encountered in the open sea would have little effect in changing the net effective buoyancy of such a unit, although there would be a considerable change in displacement during these conditions. Due to this characteristic, vertical forces which normally tend to produce rolling, pitching and heaving motions in the structure (with their corresponding stress systems) are reduced to a very low order.

The study report further states that longitudinal and transverse oscillation, normally described as pitch and roll, is considered negligible in all Seadrome lengths that would be considered practical for airport purposes. The pitch of the 72-foot long model, in waves of 70 to 80 feet in length, approximated only a 1% grade.

It is important to note from both the full-scale and model drawings that the deck maintains a planar surface with no hinge lines or other surface perturbations. A planar surface is absolutely necessary for airstrips serving aircraft landing and taking off with horizontal components of motion. Engineering concepts which permit sudden breaks in deck gradient (associated with hinged deck motions) would be untenable from the usage standpoint of fast moving aircraft.

A great number of photographs (both stills and motion pictures) were taken during the tests of the Seadrome. Figures 4 and 5 are representative groups of photographs relating to various aspects of the tests.



Figure 1. CONCEPTUAL DRAWING OF ORIGINAL SEADROME CONFIGURATION

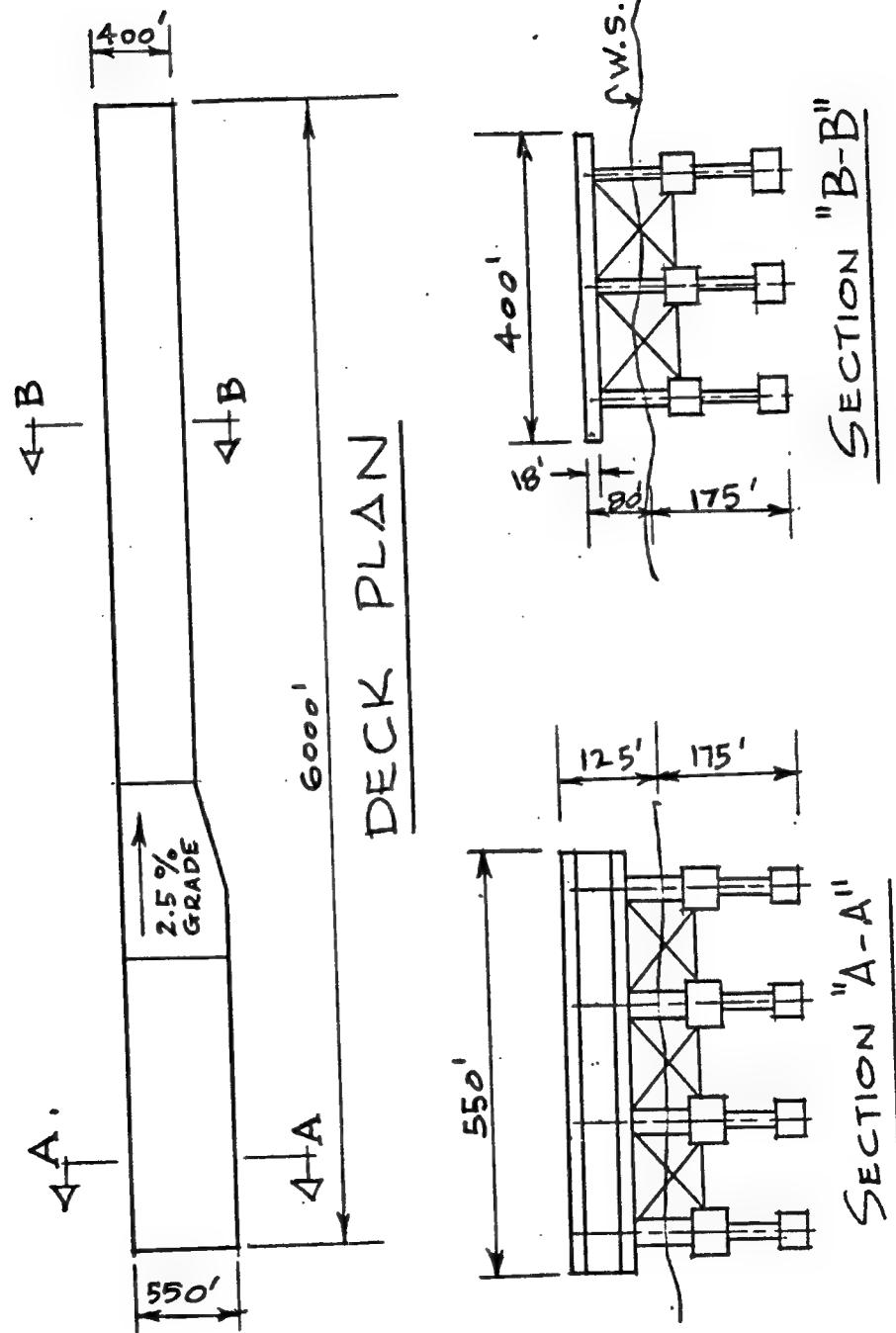


Figure 2. PLAN AND TYPICAL CROSS SECTIONS OF THE ORIGINAL SEADROME CONFIGURATION

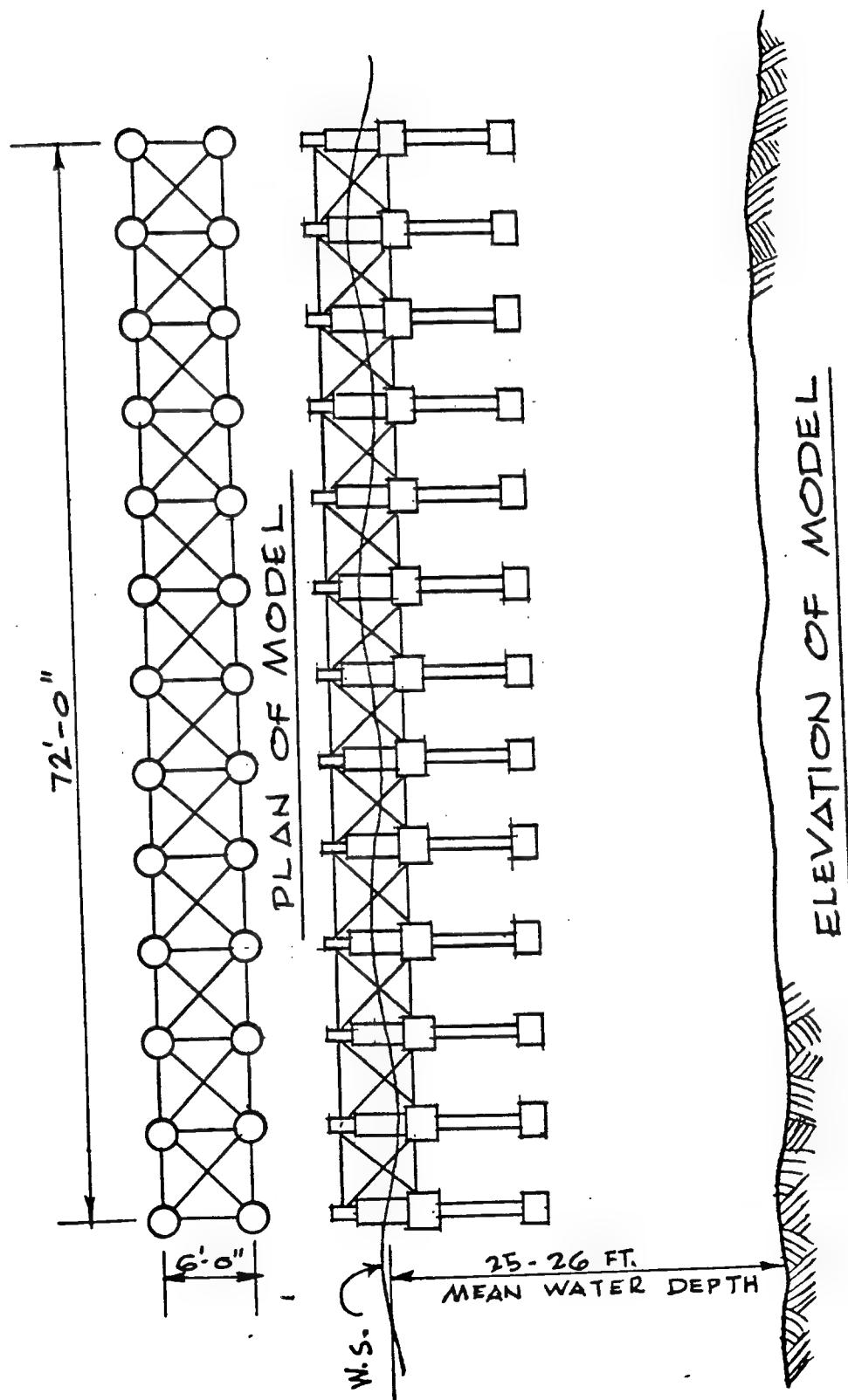


Figure 3. PLAN AND ELEVATION OF 1/25 SCALE MODEL OF SEADROME CONFIGURATION

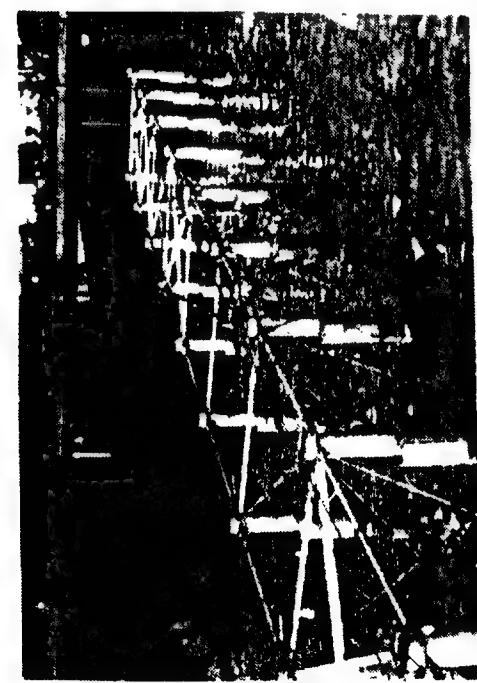


Figure 4a

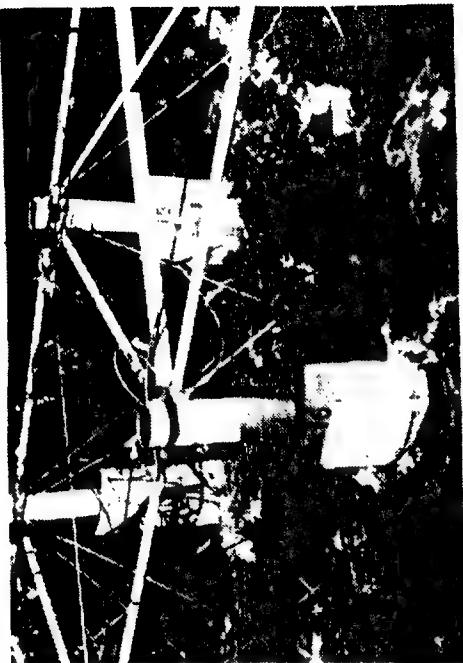


Figure 4b

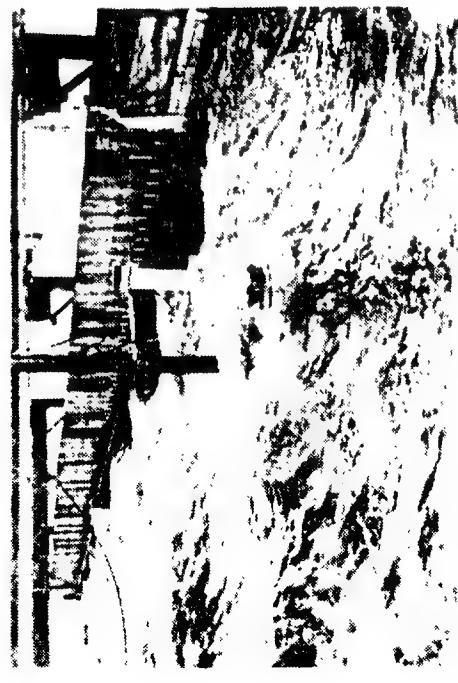


Figure 4c



Figure 4d

Figure 4. MISCELLANEOUS PHOTOGRAPHS OF THE SEADROME TESTS



Figure 5a



Figure 5b



Figure 5c

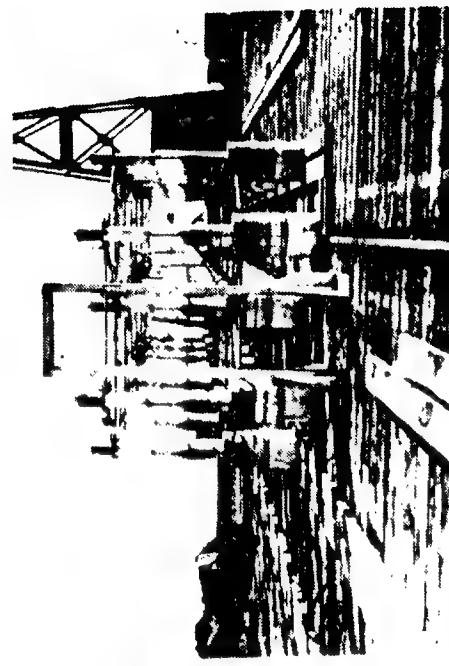


Figure 5d

Figure 5. MISCELLANEOUS PHOTOGRAPHS OF THE SEADROME TESTS

This is a partial copy of an invention disclosure developed and prepared by George W. Morgan in 1970. Patent protection was initiated by George W. Morgan in 1971.

THE SEA - HEX

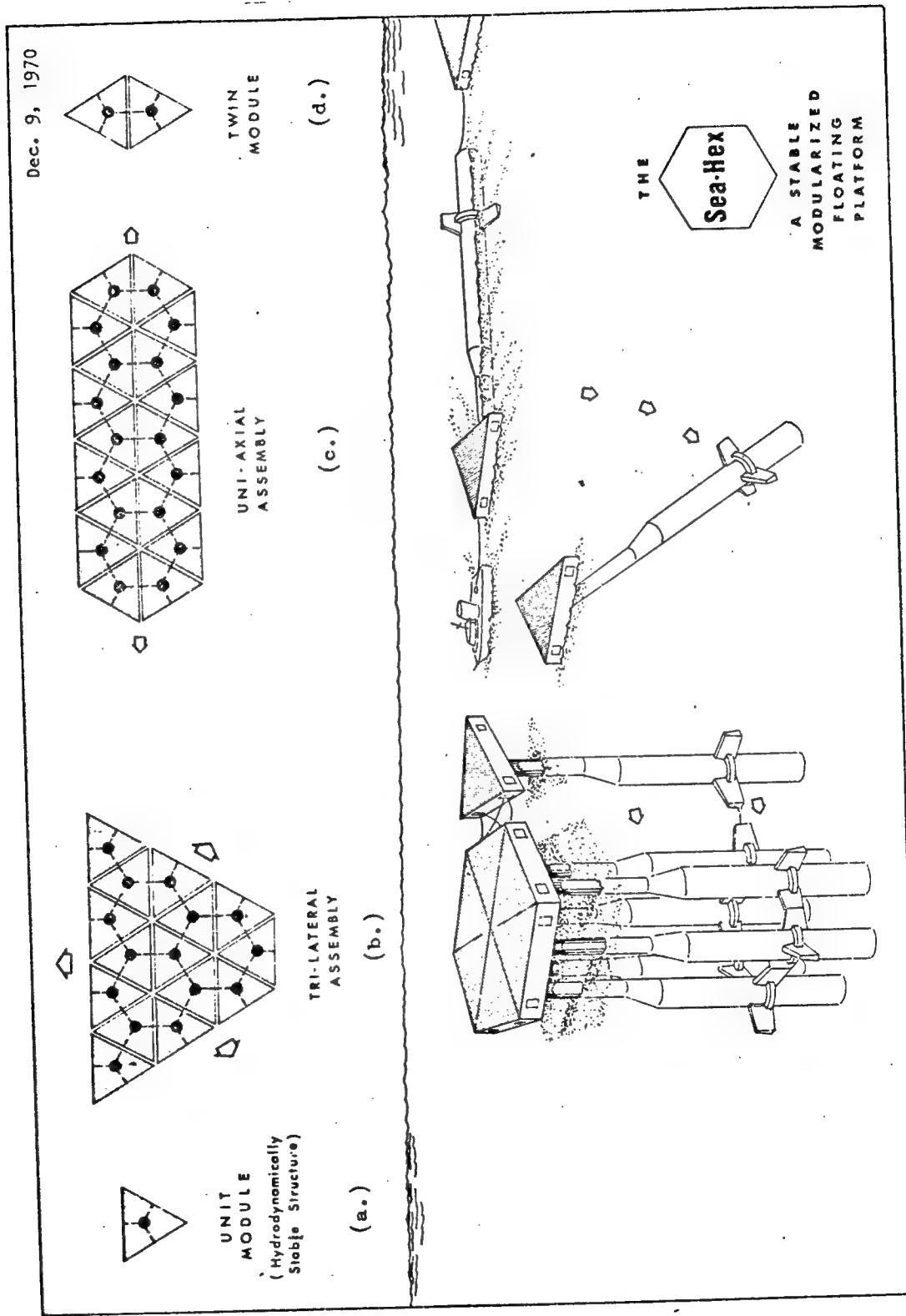
A Stable, Modularized Floating Platform

An engineering concept for platform modularization which uses basic modules to assemble

- multi-module, mid-ocean air strips
- single module research stations
- and many intermediate shapes

"Put the Hex
on the Sea . . . "





George W. Morgan, Consulting Engineer

Figure 1. GENERAL FEATURES OF THE SEA-HEX STABLE PLATFORM CONCEPT

Appendix D

Submission by
Dr. T. V. Yu



TRANSWORLD DRILLING COMPANY
POST OFFICE BOX 25861, OKLAHOMA CITY, OKLAHOMA 73125

November 8, 1971

Mr. A. J. Tachmindji, Director
Systems Evaluation Division
Institute for Defense Analyses
400 Army-Navy Drive
Arlington, Virginia 22202

Dear Mr. Tachmindji:

It was certainly a pleasure to serve on the Advisory Panel meeting on 3 November 1971 for floating platforms. Since the function of this Advisory Panel is to advise on the feasibility of the design, I shall, therefore, limit my comments to the technological aspects of this project.

My primary consideration of this design is in the area of safety of life and/or property. From the information presented at the meeting, we have touched very little on this subject. As was presented, the final platform will be composed of many modular units mated together in a certain operational location. Unless the mating operation is to be carried out in a very calm area, or is to be delayed after the sea has calmed down to a workable condition, any attempt to mate two units (each displacing about 6500 tons) into a pinpoint docking in any high sea condition is a dangerous operation which may result in loss or damage to either life or property. There are numerous instances in maritime history in this respect. Any claim that this operation can be achieved in a sea condition by exercising superb seamanship must be carefully studied.

My second point is in the area of conception. It is a fact that FLIP is a research vessel and is a very successful one for its use. However, to expand the application of FLIP into a stable working platform for a different purpose requires some evaluation. I have made a comparative table between the subject stable platform and our drilling floating stable platform. Since my experience in stable platform mission is confined only to offshore mineral operation, I have left value evaluation columns open for your use. The enclosed pictures depict the drilling platform I have told you about.

I have also taken the liberty of enclosing some actual platform operational reports for your reference; these should be treated as confidential information. I must apologize for blanking out some communications which are not related to this subject matter.

Mr. A. J. Tachmindji
November 8, 1971
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The design as submitted will work when the engineering details we discussed and other considerations are well taken care of and if its application can accomplish the mission it is required to fulfill.

I appreciate the opportunity to participate in the meeting and in the event you have any questions in this field, please feel free to contact us.

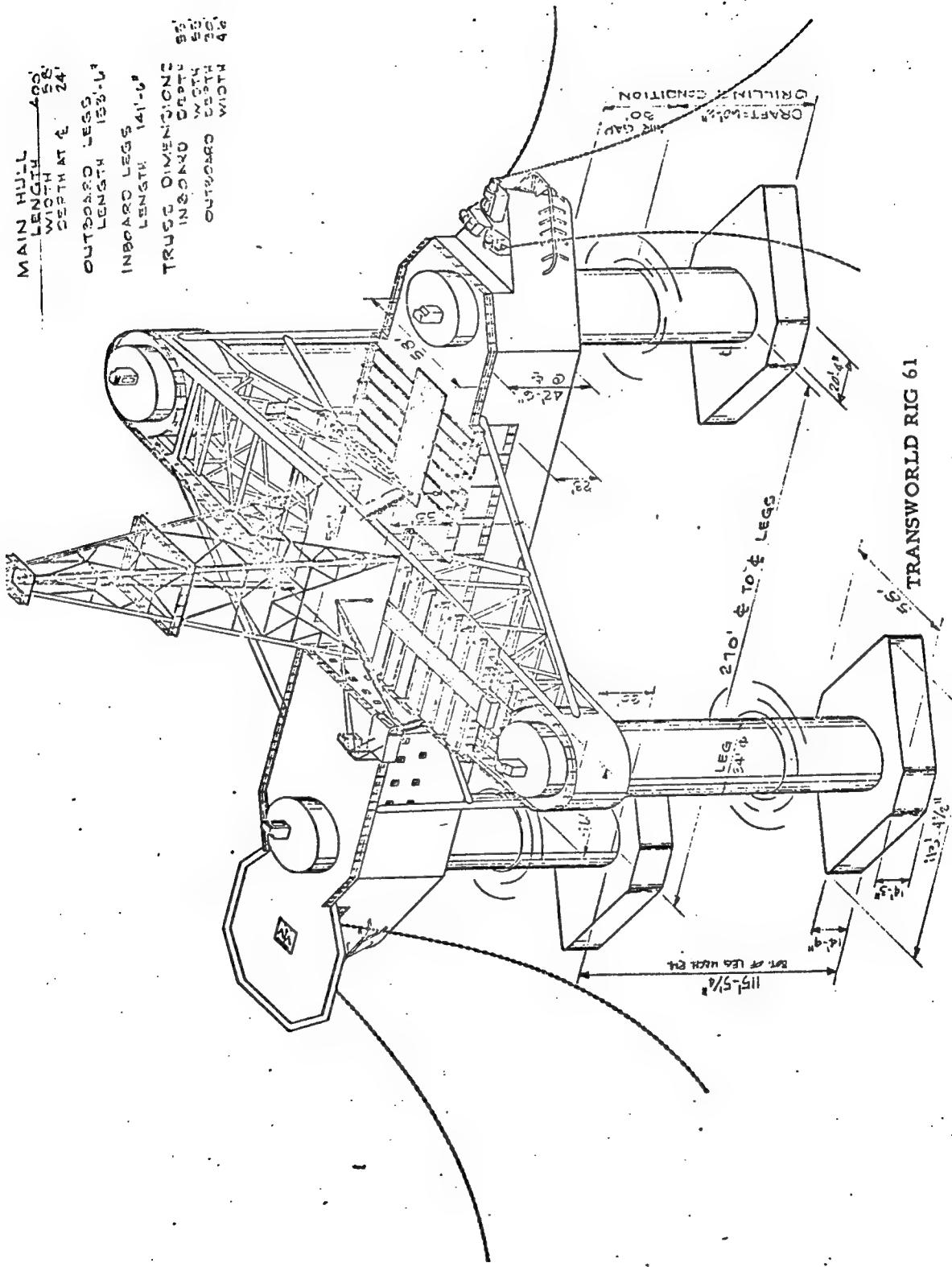
Yours very truly,

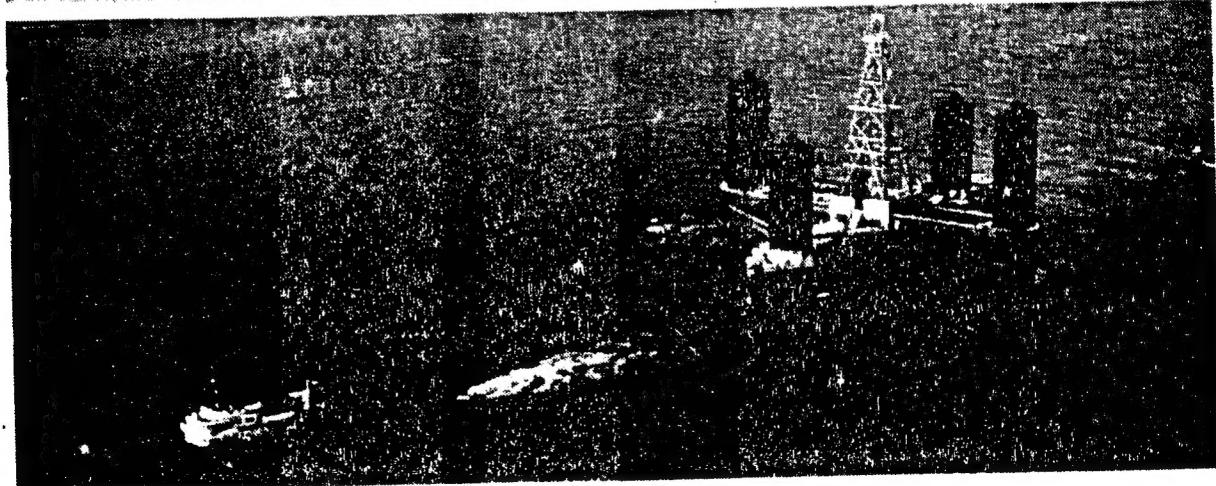
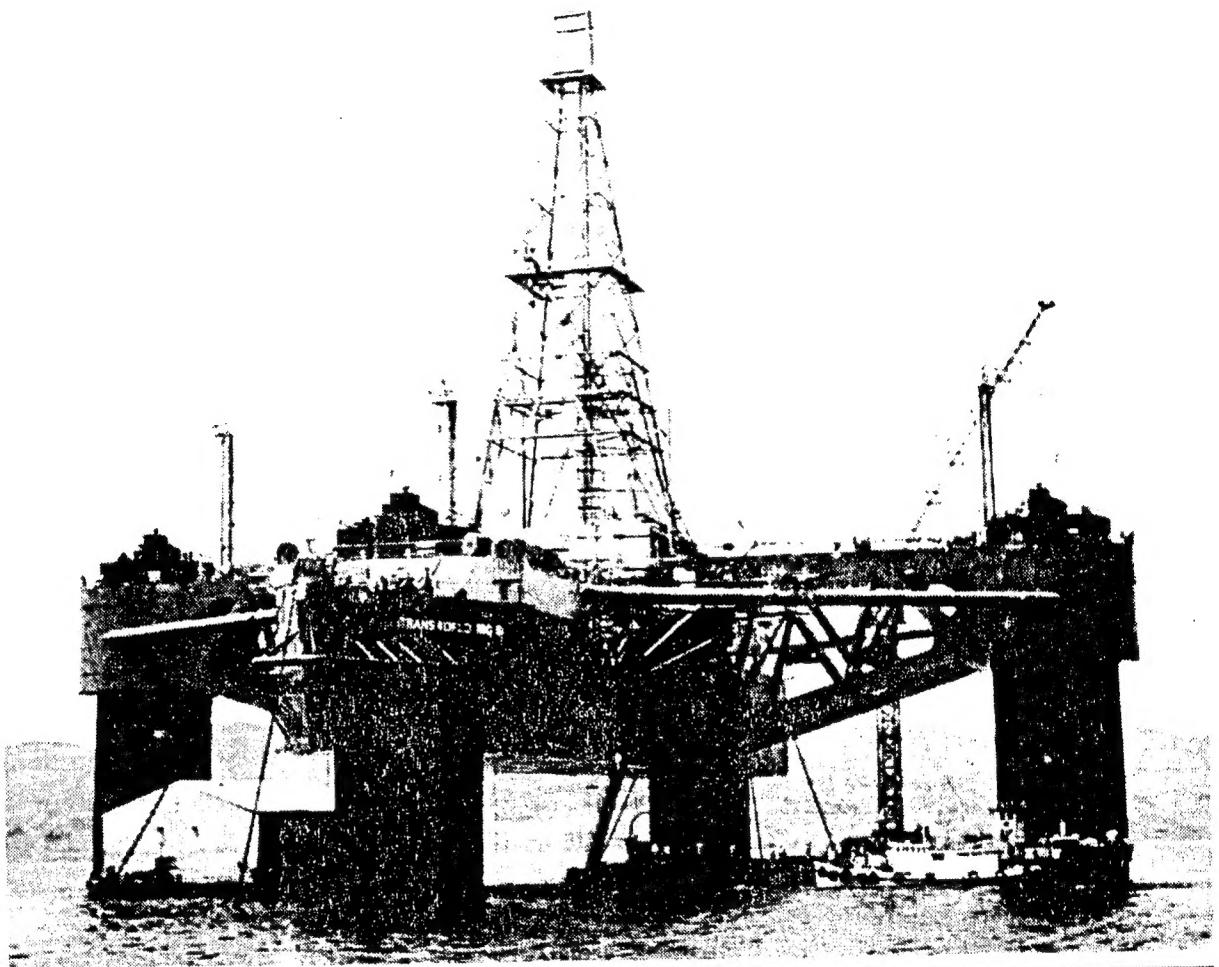


Tsi Van Yu

TVY:mkr
Enclosures

	<u>FLIP Type Platform</u>	<u>% of Value</u>	<u>Typical Drilling Platform</u>	<u>% of Value</u>
Displacement	Two Units 13,000 Tons @ 6500 Tons Per Unit		12,500 Short Tons	
Draft in Operating Mode	260 Ft.		60 Ft. to 70 Ft.	
Air Gap Clearance	40 Ft.		30 Ft. to 50 Ft.	
Towing Speed	6-7 Knots Estimated		110 Miles Per Day Actual In Sea Conditions	
Payload	Small		Over 2000 Tons Live Load Over 3000 Tons Including Machinery	
Workable Deck Area	Small		Very Large	
Accommodation	18 People		70 to 80 People	
Stability	Good		Good	
Motion Characteristics	Good		Good	
Station Keeping	Unknown		Possible	
Self-Propulsion	Impossible		Yes	
Safety Record	Unknown		Yes	
Prototype Operational Experience	No		Proven	
Composite Technology	Unproven			





Appendix E

Submission by
Dr. J. Harvey Evans

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF OCEAN ENGINEERING
CAMBRIDGE, MASS. 02139

19 November 1971
Room 5-219

Mr. A. J. Tachmindji, Director
Systems Evaluation Division
Institute for Defense Analyses
400 Army-Navy Drive
Arlington, Virginia 22202

Dear Alex:

The Annual Meeting of the Society of Naval Architects and Marine Engineers has delayed this reply to your request for a few comments in writing on the Scripps - ARPA Floating Platform review.

For me, the critical condition is with the platform modules upright and coupled, or in the process of being coupled or uncoupled. Obviously the Scripps people have spent considerable effort on just these matters (possibly excluding uncoupling). Whether or not a satisfactory mechanical link can now be devised is surely a question of high priority. To a lesser extent the same is true of the trunnion locking devices. It now occurs to me to inquire whether or not a worm gear on a quadrant fixed to the platform with the additional advantage of providing positive angular control of the platform as well, might not be most the suitable means even at some additional cost. Even under tow some other mean angle than the angle of natural repose might be decidedly preferable and it might vary with the sea state.

I am also much in favor of exploring the possibility of using cross bracing between the two modules. The more positive connection between the two elements would greatly reduce the likelihood of interference and resultant damage. Even more to the point, greater payload would be possible as the ballast now required could be significantly reduced. Alternatively, a greater air gap could be provided with no reduction of payload. It is also quite possible that careful attention to the hook-up procedure including cross bracing might reduce the relative motions of the modules, the loading on the platform links and the number of degrees of freedom required sufficiently so that the link problem would be significantly simplified. Of course, it might now be asked why not go directly to an offshore drilling or Mohole type of platform instead. However, the two module concept still has the advantage of being useful as

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individual elements or as a pair widely separated but cooperating.

The governing loadings for individual modules are likely to be longitudinal bending in waves or up-ending, lateral bending and catamaran torsion. These are being considered, it appears, and during final design stages can probably be reckoned with in whatever detail is necessary without adversely affecting the design characteristics now being converged upon.

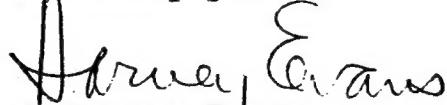
I cannot become very disturbed about the slamming or springing problems in the module under tow as considerable control could be exercised as to when towing took place and how the legs were ballasted. Also towing would be infrequent, reducing even further the possibility of arduous encounters. Slamming or impact loadings on the platform bottom is another matter but normal shipbuilding practice (or perhaps less) should suffice.

I too like the suggestion of using steel bulkheads in the legs, for the sake of easing the periphery stress problem but I cannot say I feel this solution mandatory.

Surely some better definition by ARPA of the missions to be performed is necessary. I see no real possibility of such modules being useful in extensive transverse arrays. If this limitation is acceptable I would say the design development should now be carried through the detail stage while including the exploratory investigations mentioned previously. The motion characteristics of such devices as these are quite evidently preferable to those of catamaran surface types. This is in fact a conclusion of Motherway and Heller in a paper just appearing in the October 1971 Naval Engineers Journal.

I was impressed by the evident thoughtfulness and thoroughness of the Scripps team.

Sincerely yours,



J. Harvey Evans

Professor of Naval Architecture

JHE/mcs